MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/18

ENT4046 – NANO/MICROELECTROMECHANICAL SYSTEMS

(NE)

14 MAR 2018
9.00 am – 11.00 am
(2 Hours)

INSTRUCTION TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Answer all questions.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) (i) With aid a simple diagram, briefly describe what is MEMS as a microsensor? [2 marks]

(ii) With aid simple diagrams, briefly describe the components and operation principle of a microsystem for air-bag deployment. [4 marks]

(b) (i) Name the six energy domains for signal transduction. [3 marks]

(ii) What are the advantages and disadvantages of using piezoresistors and capacitors as signal transducer ? [4 marks]

(iii) Name four popular actuation techniques for microdevices, provide one advantage for each of these technique. [4 marks]

(c) (i) Name two types of scaling law. [2 marks]

(ii) Based on rigid-body dynamics, calculate the associated changes in the acceleration, time, and power supply to actuate a MEMS component if its weight is reduced by a factor of 10. [3 marks]

(iii) A micromotor is hardly designed to be powered by the electromagnetic force. Please provide a detailed explanation based on the scaling law. [3 marks]

Continued ...

QUESTION 2

(a) A pressure sensor is fabricated from a (100) silicon. The silicon die is measured 300×300 μm^2 and 50 μm thick, the diaphragm is etched at 54.74° angle in the slope from the bottom face into the cavity, as shown in Figure Q2(a). A pressurized medium is applied at the front side of the silicon die.

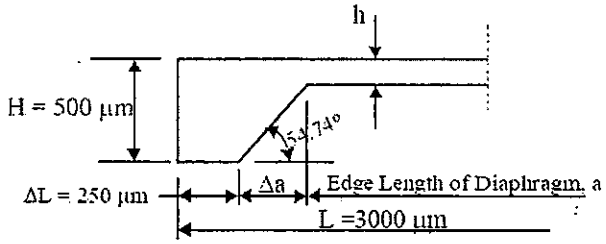

Figure Q2(a)

Find

(i) Δa in term of the diaphragm thickness, h [2 marks]

(ii) the length a of the diaphragm in term of h [2 marks]

(iii) maximum pressure p in term of h if the maximum stress of silicon die is 350 MPa, given by the following formula: [3 marks]

$$\sigma_{max} = \frac{0.308pa^2}{h^2}$$

(iv) maximum pressures if h = 300, 200 and 100 μm. [6 marks]

(b) A microdevice component, 5 g in mass, is attached to a fine strip of silicon, as shown in Figure Q2(b). The equivalent spring constant of the strip is 18,240 N/m. Both the mass and the strip-spring are made of silicon. The mass is pulled down by 5 μm initially and is released at rest. Determine

(i) the natural frequency of the simulated mass-spring system [3 marks]

(ii) the maximum amplitude of vibration [6 marks]

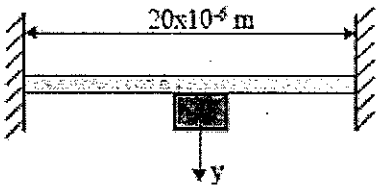

Figure Q2(b)

(c) The use of continuous mechanics theory using average material behavior in assessing the stresses in thin films is often not ideal, what are the possible stresses to the total stress σ_T ? [3 marks]

Continued ...

QUESTION 3

(a) A parallel-plate capacitor has the following dimensions of $L = W = 1000\ \mu m$ with a gap $d = 2\ \mu m$. The dielectric medium between the two plates is air with relative permittivity $\varepsilon_r = 1$ and the permittivity of free space is $\varepsilon_0 = 8.85\times10^{-12}$ F/m.

(i) Sketch the capacitor and calculate the capacitance. [2 marks]

(ii) Derive the electrostatic forces in W- and L-direction. [4 marks]

(iii) Calculate the force in either W- or L-direction if the parallel plates are misaligned by 20 percent in both directions, and pyrex glass is used as the dielectric material and there is no gap change with applied voltage at 70V. [3 marks]

(iv) Sketch two microgrippers and equivalent electrical circuits that are based on simple parallel-plate electronstatic force. [4 marks]

(b) A parallel-plate capacitor with an area of $100 \times 100\ \mu m^2$ is supported by four cantilevel beams. The plate is made of polysilicon that is $2\mu m$ thick. The distance between the bottom of the plate and substrate is $1\ \mu m$. Each cantilever is $400\ \mu m$ long, $25\ \mu m$ wide (w) and $0.1\ \mu m$ thick (t). The mass density of polysilicon is 2330 kg/m^3, Young's modulus of polysilicon E is 150 GPa and the moment of inertia for cantilever I is given by wt^3.

Find

(i) the force constant k associated with all four support beams [3 marks]

(ii) the static displacement δ if the acceleration is 1g [2 marks]

(iii) the relative change of capacitance ΔC after the static displacement [2 marks]

(c) With aid of simple diagrams, briefly describe contactless conductivity detection method for capillary electrophoresis of ion specie, for examples Li^+, Na^+, Mg^{2+}, Ca^+, K^+, and NH^{4+}.

[5 marks]

Continued ...

QUESTION 4

(a) (i) With aid a block diagram, provide an overview of the *initial* mechanical design consideration of microsystems. [5 marks]

(ii) Name three manfucturing processes that are commonly used for fabricating various types of microdevices. [3 marks]

(iii) For fabrication of a micropressure sensor, which of the above three manufacturing processes would you recommend. Give justification. [2 marks]

(b) (i) Briefly explain what are interfaces in microsystem packaging? [2 marks]

(ii) For the case of optical MEMS, what should be included in the interface design ? [3 marks]

(c) (i) Name the three levels of MEMS packaging. [3 marks]

(ii) What are major reliability issues for the Level (1+2) packaging of MEMS, or microsystem? [3 marks]

(iii) Suggest the common materials required for microsystem packaging as listed in Table Q4 below: [4 marks]

Table Q4

Microsystem Components	Available Materials
Die	
Insulators	
Die Bonding	
Wire Bonding	

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